SPECIFICATION

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APPARATUS AND METHOD TO CONTROL FORCE EXERTED ON STEAM TURBINES BY INLET PIPES

Background of Invention

[0001] This invention relates generally to steam turbines, and particularly to steam turbine steam inlet and outlet piping that includes portions fabricated from shape memory alloys.

[0002] Steam and gas turbines are used, among other purposes, to power electric generators, and gas turbines also are used, among other purposes, to propel aircraft and ships. A steam turbine has a steam path which typically includes, in serial-flow relationship, a steam inlet, a turbine, and a steam outlet. A gas turbine has a gas path which typically includes, in serial-flow relationship, an air intake (or inlet), a compressor, a combustor, a turbine, and a gas outlet (or exhaust nozzle). Compressor and turbine sections include at least one circumferential row of rotating blades. The free ends or tips of the rotating blades are surrounded by a stator casing.

[0003] The steam inlet piping is installed at room temperatures when the steam turbine is assembled. During startup and operation, the pipes expand and can exert force and moments on the steam turbine casing. These forces can distort the casing of the steam turbine which can cause rubbing of the internal moving components of the turbine.

Summary of Invention

[0004]

In one aspect, a steam turbine is provided that includes a steam inlet pipe coupled

to a steam inlet port in a steam turbine housing. At least a portion of the steam inlet pipe is fabricated from at least one of a shape memory alloy having a memorized activated configuration and a negative thermal expansion ceramic having an activated configuration.

[0005] In another aspect, a method of controlling forces exerted on a steam turbine by a steam inlet pipe is provided. The steam turbine includes a steam inlet pipe coupled to a steam inlet port in a steam turbine housing. The method includes fabricating at least a portion of the steam inlet pipe from at least one of a shape memory alloy having a memorized activated configuration and a negative thermal expansion ceramic having an activated configuration, installing the steam inlet pipe with the at least a portion of the steam inlet pipe in an initial configuration at a first temperature, and heating the at least a portion of the steam inlet pipe with steam flowing into the steam turbine to a second temperature which reconfigures the at least a portion of the steam inlet pipe to the activated configuration.

Brief Description of Drawings

[0006] Figure 1 is sectional schematic view of a steam turbine.

[0007] Figure 2 is a schematic representation of the steam turbine shown in Figure 1 with a steam input line.

[0008] Figure 3 is a schematic representation of the steam input line shown in Figure 2 in a deactivated state.

[0009] Figure 4 is a schematic representation of the steam input line shown in Figure 2 in an activated state.

[0010] Figure 5 is a schematic representation of the steam turbine and steam input line shown in Figure 2 in a heated state.

Detailed Description

[0011]

A steam turbine that includes a steam input line having at least a portion of the input line fabricated from a shape memory alloy having a memorized activated configuration and/or a negative thermal expansion ceramic having an activated

configuration is described in detail below. The shape memory alloy and/or the negative thermal expansion ceramic is used to control the steam input line pipe expansion/contraction during the steam turbine operation. A shape memory alloy, for example NiTi, can be formed into any desired shape. When heat is applied to activate the shape memory alloy, the material reconfigures to a pre-programmed shape. Specifically, when the steam pipe is heated, the shape memory alloy reconfigures to a shape that compensates for the expansion of the remainder of the steam pipe to prevent steam pipe deformation which reduces the stress forces that are transmitted to the steam turbine shell.

[0012] Referring to the drawings, Figure 1 is a sectional schematic view of a steam turbine 10. Steam turbine 10 includes a shaft 12 passing through turbine 10 and supported at each end by bearing supports 14. A plurality of turbine blade stages 16 are connected to shaft 12. Between turbine blade stages 16 there is positioned a plurality of nonrotating turbine nozzles 18. Turbine blades 16 are connected to turbine shaft 12 while turbine nozzles 18 are connected to support members or nozzle diaphragms 20 attached to a housing or shell 22 surrounding turbine blades 16 and nozzles 18. Steam inlet ports 24 connect to a source of high temperature steam by steam input line 28 (shown in Figure 2) and direct the steam into turbine 10. Main steam control valves 26 control the flow of steam into turbine 10. Steam is directed through nozzles 18 to impact blades 16 causing blades 16 to rotate along with turbine shaft 12. Some of the steam is admitted into extraction chambers 30 and 32 and a predetermined amount of steam is intentionally piped off to various feedwater heaters (not shown). After the remaining steam passes through all of the turbine blades, it exits through steam exhaust casing 34 and exhaust outlet 36 and is directed back to a condenser (not shown) and then to a reheater and/or boiler (not shown) to be reconverted into steam.

[0013] Figure 2 is a schematic representation of steam turbine 10 with steam input line or pipe 28 connected to steam inlet port 24. Steam input pipe 28 includes a plurality of pipe elbows 38 (one shown). During start-up, as steam passes through steam pipe 28, steam pipe 28 and pipe elbow 38 expand causing a deformation of steam pipe 28 which imparts stress forces on turbine shell 22. These stress forces on turbine shell 22 can cause a deformation of shell 22 which can exceed the tolerances between the

moving parts inside shell 22 causing rubbing of turbine blades 16 with shell 22.

[0014] Referring also to Figures 3 and 4, in an exemplary embodiment of the present invention, steam input line 28 includes a portion 40 fabricated from a shape memory alloy and/or a negative thermal expansion ceramic. The remaining portions 42 are fabricated from any other suitable material such as, for example, steel, stainless steel, and cast iron.

[0015] Various metallic materials are capable of exhibiting shape-memory characteristics. These shape-memory capabilities occur as the result of the metallic alloy undergoing a reversible crystalline phase transformation from one crystalline state to another crystalline state with a change in temperature and/or external stress. In particular, alloys of nickel and titanium exhibit these properties of being able to undergo energetic crystalline phase changes at ambient temperatures, thus giving them a shape-memory. These shape-memory alloy materials, if plastically deformed while cool, will revert to their original, undeformed shape when warmed. These energetic phase transformation properties render articles made from these alloys highly useful in a variety of applications. An article made of an alloy having shape-memory properties can be deformed at a low temperature from its original configuration, but the article "remembers" its original shape, and returns to that shape when heated.

[0016] For example, in nickel-titanium alloys possessing shape-memory characteristics, the alloy undergoes a reversible transformation from an austenitic state to a martensitic state with a change in temperature. This transformation is often referred to as a thermoelastic martensitic transformation. The reversible transformation of the NiTi alloy between the austenite to the martensite phases occurs over two different temperature ranges which are characteristic of the specific alloy. As the alloy cools, it reaches a temperature M_s at which the martensite phase starts to form, and finishes the transformation at a still lower temperature M_f. Upon reheating, it reaches a temperature A_s at which austenite begins to reform and then a temperature A_f at which the change back to austenite is complete. In the martensitic state, the alloy can be easily deformed. When sufficient heat is applied to the deformed alloy, it reverts back to the austenitic state, and returns to its original configuration. Suitable shape

memory alloys include, but are not limited to, NiTi, NiTiCu, CuZnAl, CuAlNi, NiTiFe, CuAlNiTiMn, TiNiPd, TiNiPt, NiTiPd, and TiNiHf.

[0017] Also, some ceramic materials and composite materials exhibit negative thermal expansion characteristics. Particularly, these negative thermal expansion materials contract when heated. When portion 40 of steam line 28 is fabricated from a negative thermal material, portion 40 of steam line 40 contracts when heated by flowing steam while portions 42 of steam line expand. In the exemplary embodiment, the size of portion 40 and the particular negative thermal material is chosen so that the contraction of portion 40 is approximately equal to the expansion of portions 42 of steam line 28, thus minimizing the stress forces imparted on steam turbine 10. Figure 3 shows a representation of portion 40 and portions 42 of a "cool" steam line 28 in an initial configuration. Figure 4 shows a representation of portion 40 and portions 42 of a "hot" steam line 28 with steam flowing through steam line 28. Figure 4 shows the expansion of length of portions 42 and the contraction of portion 40. Suitable negative thermal expansion ceramics include, but are not limited to ZrW_2O_8 and ZrP_2O_7.

[0018] Further, portion 40 of steam line 28 can be fabricated from a shape memory material that has a memorized activated configuration that has a length that is less than a deactivated configuration length. Particularly, as steam line 28 is heated by flowing steam, the shape memory material that forms portion 40 changes from its non-activated configuration to its activated configuration which has a length that is less than the non-activated configuration while portions 42 of steam line expand. In the exemplary embodiment, the difference in length between the non-activated configuration and the activated configuration is selected to be approximately equal to the expansion of portions 42 of steam line 28, thus minimizing the stress forces imparted on steam turbine 10.

[0019]

Figure 5 is a schematic representation of steam turbine 10 and steam line 28 heated by steam flowing through steam line 28. Because of an increase in temperature caused by the flowing steam, steam line 28 expands and stress forces deform pipe elbow 38. In this heated state, there are high stresses on pipe elbow joints 44 and 46, and on steam line to inlet port joint 48. To alleviate the stresses in steam line 28,

steam pipe elbow 38 is fabricated from a shape memory material with a memorized activated configuration of a "deformed" elbow as shown in Figure 5. When steam pipe elbow 38 is heated by the flow of steam it reconfigures to the memorized activated "deformed" configuration which eliminates the stresses in elbow joints 44 and 46 and reduces the stresses in joint 48 between steam line 28 and steam inlet port 24 in steam turbine casing 22. The "deformed" configuration of pipe elbow 38 has an elbow angle B that is different from an elbow angle B of the non-activated configuration of elbow 38 (shown in Figure 2). The amount of deformation or change of elbow angle B between the non-activated configuration and the activated "deformed" configuration is selected to reduce the stress on turbine casing 22 caused by the expansion of steam pipe 28 when heated by the flow of steam.

[0020] While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.